HD Radio™ System Test Report

Compatibility and Performance Tests

at Elevated FM Digital Power Level

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This report provides the results of iBiquity's recent test program designed to assess the benefits and potential implications of an increase in the digital power used in the FM HD Radio system. This test program demonstrated a 10 dB increase in digital power will provide broadcasters and the listening public with even greater coverage of HD Radio broadcasts without a meaningful increase in the risk of interference to adjacent channel analog broadcasts in the vast majority of cases. iBiquity recommends industry support for an increase in digital power to enhance the ability of FM stations to offer listeners the benefits of digital broadcasting.

1. Backgound

The HD Radio system allows broadcasters to upgrade to digital AM and FM broadcasting without the need for additional spectrum and without causing harmful interference to co- and adjacent channel stations. More than 1,650 stations currently offer digital broadcasts using iBiquity's HD Radio technology. These digital broadcasts reach all 50 states. More than 800 of these stations offer multicast programming. Since the introduction of experimental HD Radio broadcasts almost ten years ago and the commencement of widespread commercial service in 2002, there have been virtual no reports of harmful interference from HD Radio broadcasts to existing analog FM programming.

Existing FM HD Radio broadcasts set the digital power level 20 dB below the analog power of the station. Extensive laboratory and field testing of the HD Radio system conducted several years ago under the auspices of the National Radio Systems Committee (NRSC) demonstrated that the HD Radio system operating with this digital power level provides good digital coverage along with excellent protection of existing analog services. Real world experience with the HD Radio system operating on commercial radio stations has demonstrated the system's ability to provide coverage to a station's protected service area in most cases. However, the system has not been able to deliver digital coverage that fully replicates existing analog coverage on all stations. With the proliferation of digital broadcasts throughout the country, broadcasters have become comfortable that the introduction of digital broadcasting does not present a credible risk of harmful interference to existing analog broadcasting. As a result, broadcasters are seeking an increase in digital power levels to enhance digital coverage, recognizing an increase of this nature will not create a substantial risk of interference to analog operations.

2. Overview of Test Program

The test program summarized in this report was designed to assess the impact of a 10 dB increase in digital power. The program was divided into two segments. The first half of the test program analyzed the extent of digital coverage at the higher power level. The tests compared digital coverage at existing digital power levels 20 dB below analog power with digital broadcasts at 10 dB below analog power. This represents a 10 dB increase in digital power relative to a station's existing analog power levels. The second portion of the test program was designed to assess the compatibility of this higher digital power level with analog operations on first adjacent stations.

Three geographic areas were selected for the test program: (i) New York/Connecticut/Rhode Island; (ii) Detroit and (iii) Los Angeles/San Diego/Santa Barbara. The first region provided an opportunity to study coverage and compatibility issues in an area characterized by varied terrain (rolling hills, water, etc.), multipath interference and closely spaced stations. The Detroit area is characterized by flat terrain and extensive analog coverage. The Southern California region afforded the opportunity to study the power increase in an area with terrain obstructions and high power analog operations. In each case, an existing HD Radio station in the market was selected to increase its digital power to 10 dB below the analog power. A series of coverage tests were conducted. Audio samples of analog audio on first adjacent stations were collected for later subjective evaluation to determine the compatibility of the higher power digital broadcasts with existing analog operations. Additional coverage tests were conducted in New Jersey focused specifically on Class A stations.

For the coverage tests, a series of radials were run from each station at the existing digital power level and at the higher digital power level. From these tests, maps were produced showing existing digital coverage in each market and the digital coverage attained at the higher power level. Detailed results are presented below and in Appendix B.

The compatibility test program commenced with the recording of analog audio from first adjacent FM stations with the host station power level set at the existing - 20 db power level and at the higher - 10 db power level. The analog audio samples were submitted for subjective evaluation to determine whether the increase in digital power of the host station had a harmful impact on the listening experience for adjacent channel analog operations. The detailed results presented below and in Appendix C demonstrate that in the vast majority of cases, the increase in digital power will not create a meaningful increase in the risk of interference to analog broadcasts.

3. Coverage Results

In all cases, the increased digital power level significantly improved digital coverage. In the Northeast and in Southern California the power increase resulted in an extension of digital coverage by approximately 25%. In Detroit, the flat terrain resulted in a 33% increase in the distance covered by the digital signal. Figure 1 below shows the results for the Detroit market.

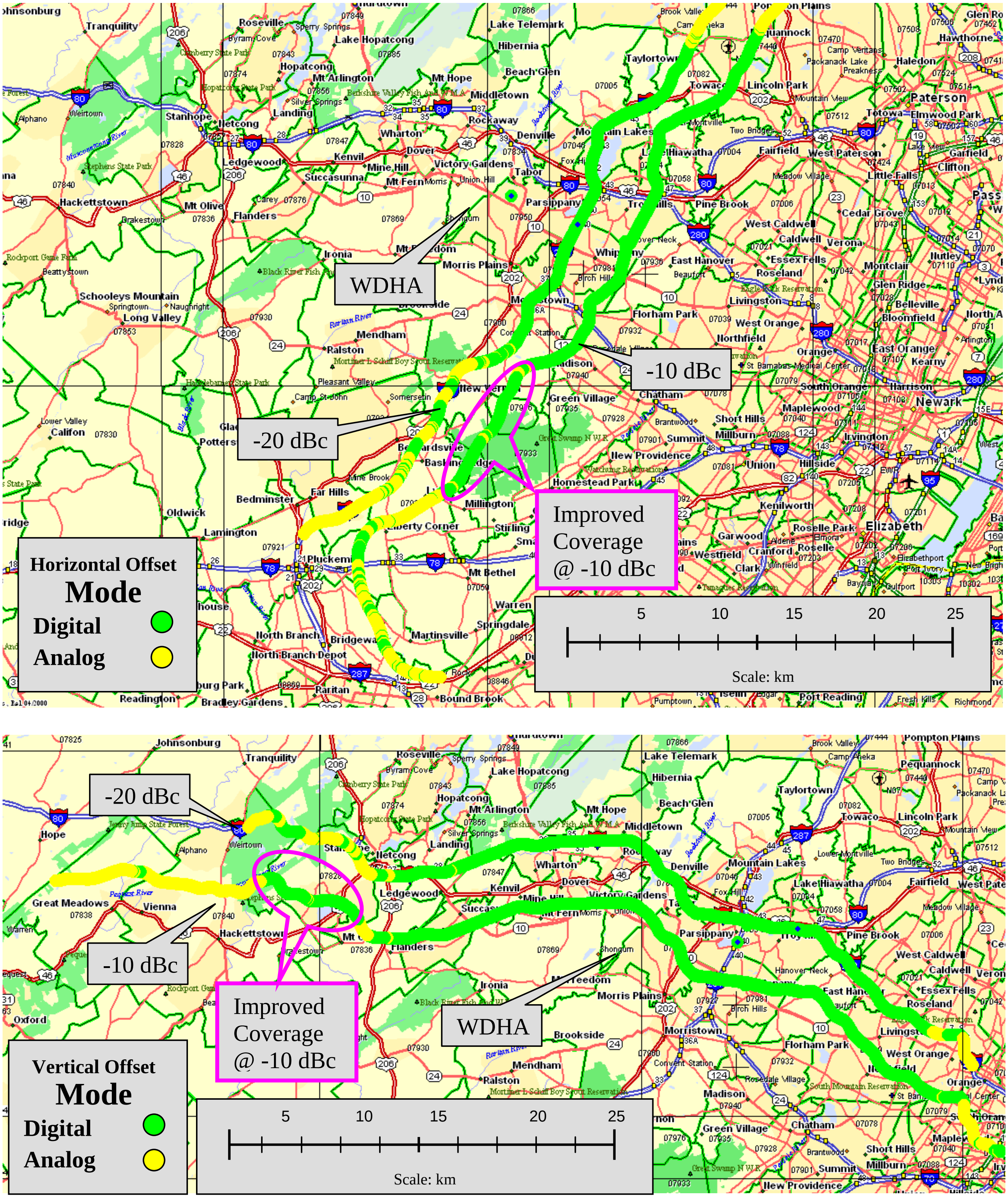


Figure 1 - WDHA Performance

In all cases, the increased digital power resulted in a noticeable reduction in digital drop outs in previously shadowed or problematic areas. In the case of Hartford, Connecticut and Ontario, California, the higher digital power level allowed the host stations to provide reliable coverage in these important markets that were not receiving adequate digital service. The results in Hartford, Connecticut showing the improved coverage at higher power are shown in Figure 2.

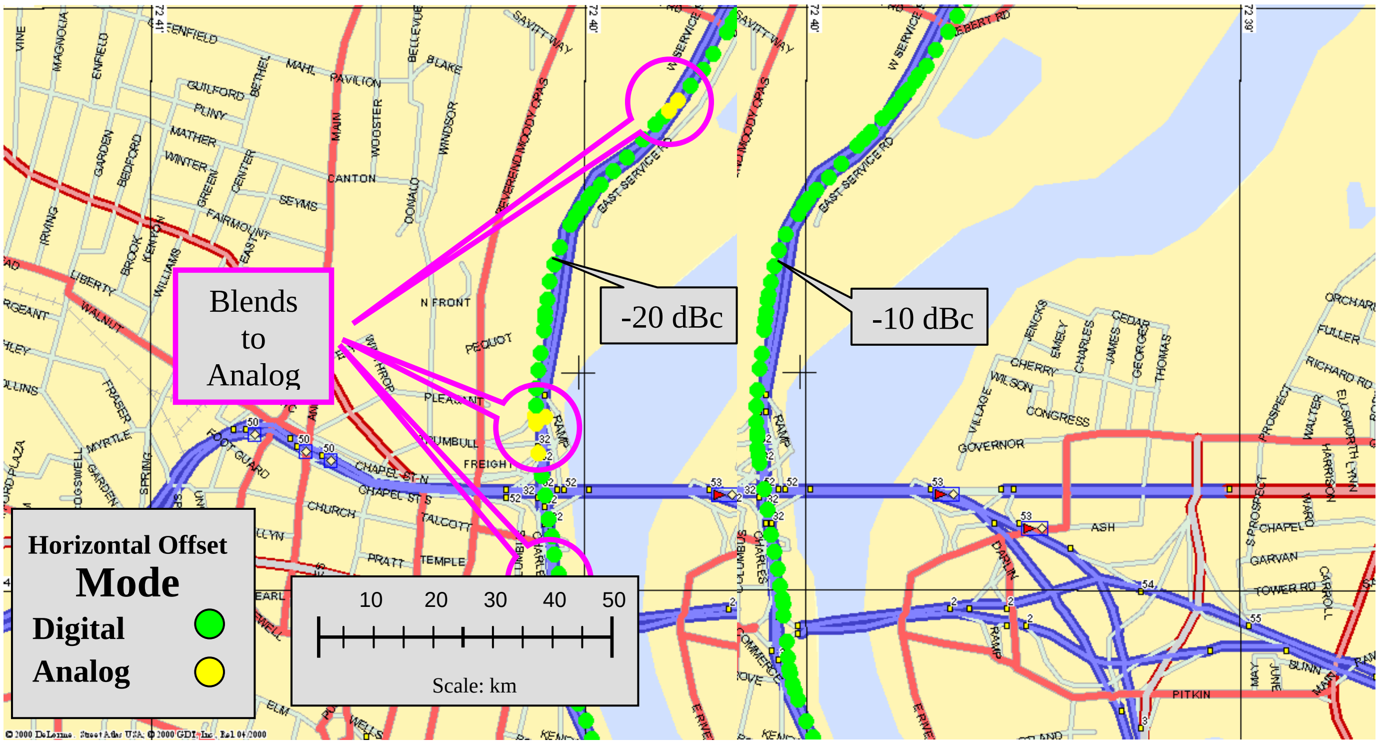


Figure 2 - WKCI Performance in Hartford, Connecticut

Similar results can be seen from the California coverage tests illustrated in Figures 3 and 4.

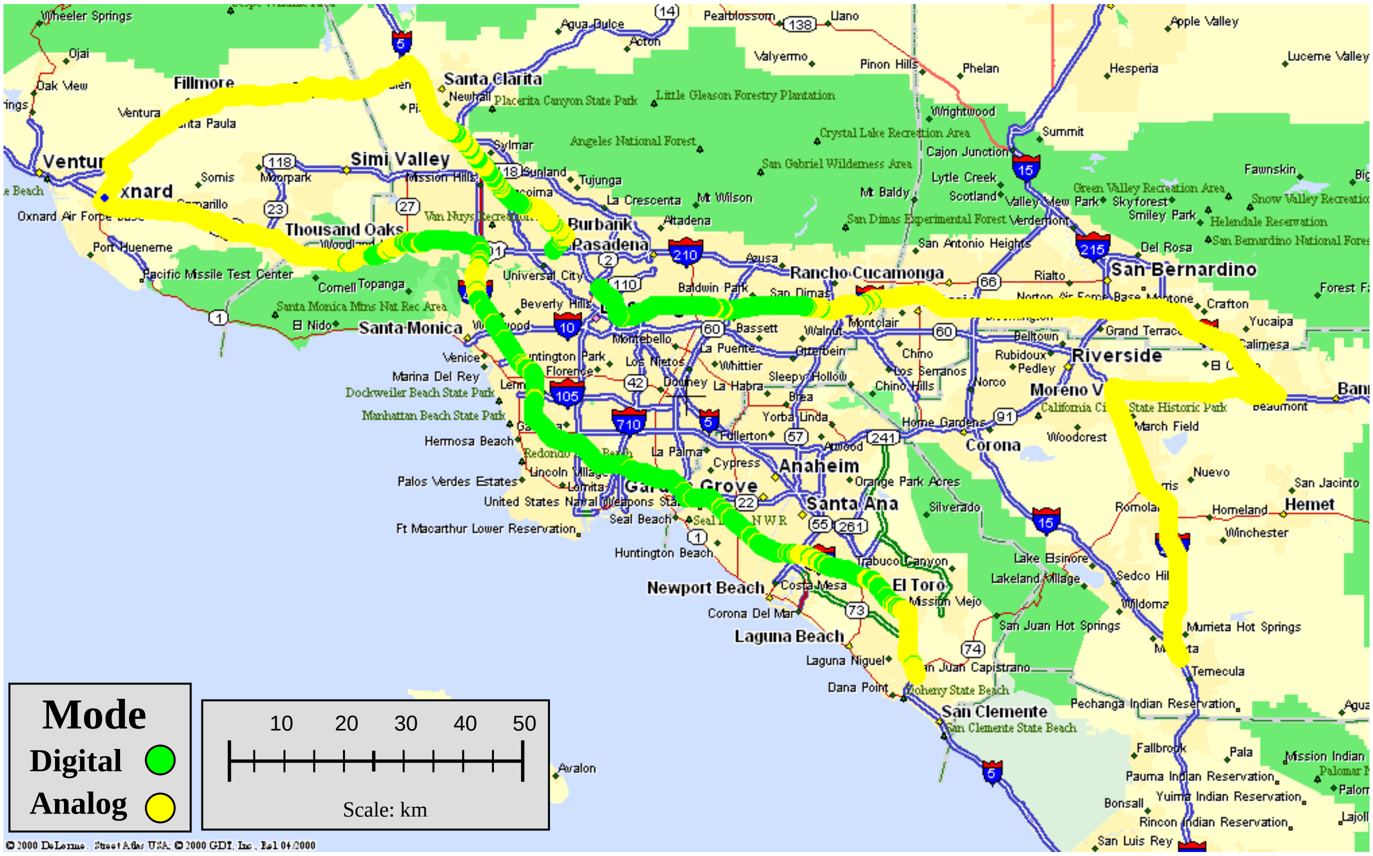


Figure 3 – KOST Performance @ -20 dBc

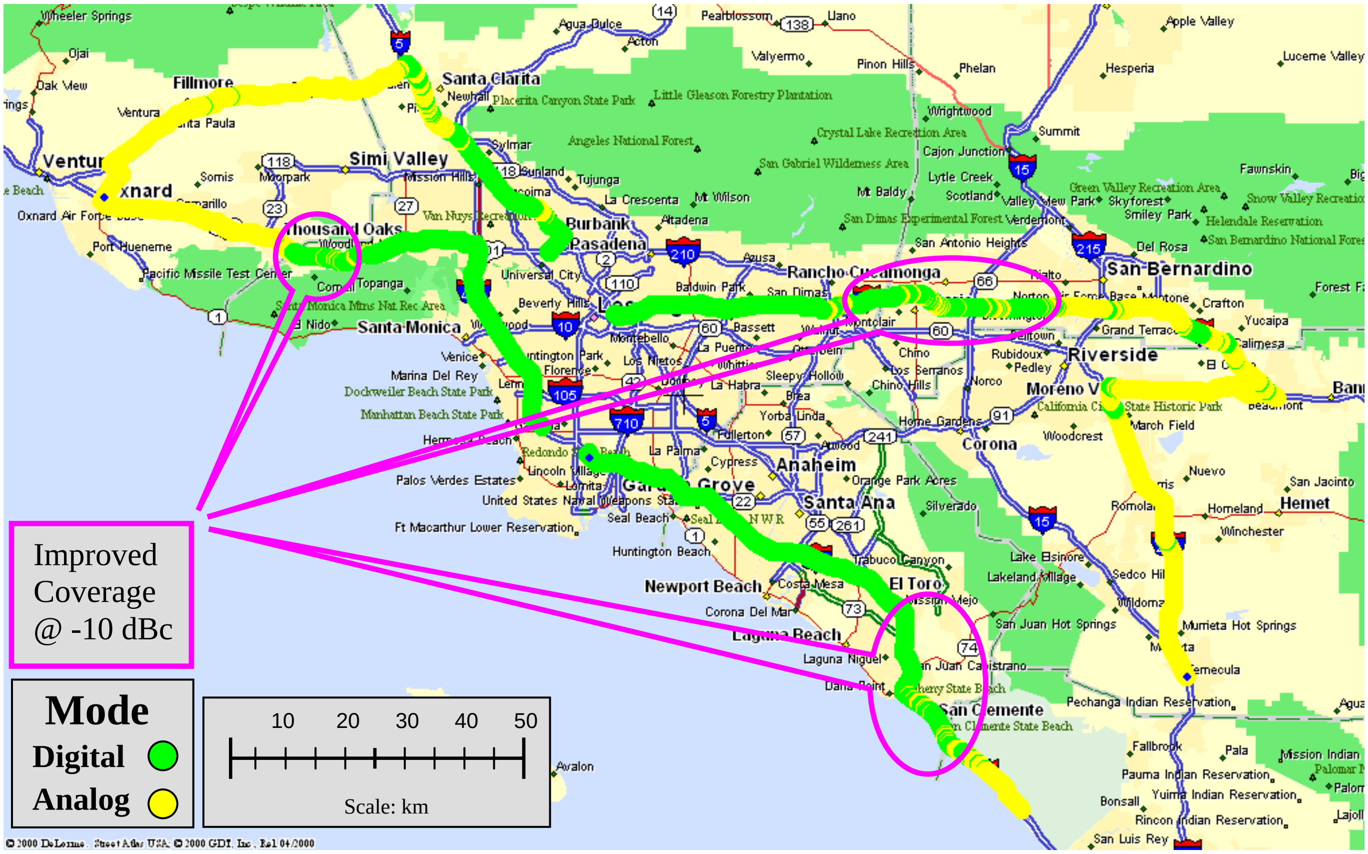


Figure 4 – KOST Performance @ -10 dBc

The Class A coverage tests conducted using two stations in New Jersey demonstrated the significant benefit this power increase will provide for these lower power stations. Due to the lower analog power of these stations, digital operations at the – 20 dB power level can fall below the overall noise floor. In those cases, digital coverage may be limited. At – 10 dB, these stations experienced a dramatic increase in digital coverage. As is explained in greater detail in Appendix B, for WRAT, there was a 67% increase in overall digital coverage. For WJRZ, overall coverage area increased by 100%.

Detailed maps and complete coverage information comparing existing and higher power levels can be found in Appendix B.

4. Compatibility Results

The compatibility tests were structured to compare the impact of digital operations at existing - 20 db digital power levels and the proposed -10 dB digital power level. In both cases, the tests were designed to assess the impact of the digital signal at a particular power level on existing analog broadcasts. The test program was used to determine whether the use of the higher – 10 dB digital power would create meaningful new risk of interference for existing analog operations.

The test program was conducted in two phases. In the first phase, analog audio was collected with a digital broadcast operating at the existing – 20 dB power level and then with the same station operating at the higher – 10 dB power level. In both cases, the analog audio was collected from first adjacent stations that would be viewed as most at risk of interference from the digital signal. At each power level audio was collected at (i) approximately +6 dB D/U ratio representing the protected contour of the desired analog station and (ii) approximately 0 dB D/U ratio representing an area outside the station's protected contour and at the edge of reliable analog reception. Either identical or similar programming was broadcast at the two power levels to facilitate comparison of the impact of the digital signals. In the second phase, the audio samples were sent to Salisbury University for formal subjective evaluation of the audio using general population listeners. A detailed explanation of the audio collection procedures and the stations used for the compatibility testing can be found in Appendix A. A complete report on the subjective evaluation methodology and the results of the subjective evaluation can be found in Appendix C.

The subjective evaluation program established that in the vast majority of circumstances, the increase in digital power will not result in a meaningful increase in the potential for harmful digital to analog interference.

The test program examined a variety of common station configurations. Audio was recorded from four interference scenarios. In the first test scenario, a Class B digital interferer was measured against a Class B desired analog signal. In the second scenario, the impact of a Class B digital interferer was measured in a short-spaced situation against a Class B desired analog signal. "Short-spaced" refers to the lack of appropriate geographic separation. The coverage areas of the adjacent channel stations may overlap or one station's coverage area may be within the coverage area of another station. In the third scenario, a Class "Super B" digital interferer was measured against a Class "Super B" desired analog signal. Finally, in the fourth scenario a Class "Super B" digital interferer was measured against a Class B desired analog signal. Table 1 lists the conditions recorded for use in subjective testing:

Condition	**Host (digital)Station**	**1st Adjacent (analog) Station**
"B" to "B"	WKCI	WWBB and WCBS
"B" to "B" Short Spaced	WCSX	WXKR
"Super B" to "B"	KOST	KSCF
"Super B" to "Super B"	KOST	KVYB

Table 1: Conditions used in subjective testing

In each condition, audio recordings were made using six commercially available radio receivers representing typical market segments. Table 2 lists the receivers used.

Receiver	Model No.	Market Segment
Bose	AWR1B2	Table top
Delphi	28061577	Automobile OEM
JVC	KD-HDR1	HD Radio receiver (analog only)
Onkyo	TX-SR504	Home
Pioneer	DEH-1800	Automobile
Tivoli	Model 2	Table top

Table 2: Receivers used for subjective testing

4.1 Compatibility at the Protected Contour

Figure 5 shows the overall results at the station protected contour. At the protected contour participants rated -10 dB and -20 dB similarly in B to B, Super B to B and Super B to Super B. In B to B short spaced, participants rated music, speech and voiceover higher at -20 dB. As would be expected the largest difference is seen in speech, where background noise can be both heard most clearly and interferes most directly with intelligibility. From these results it can be predicted that in the majority of cases listeners of adjacent channel analog stations would not experience a meaningful impact from the increase in digital power. In the case of the short spaced stations where the analog station broadcasts a speech or voiceover format, the increase in adjacent channel digital power may increase the potential impact on the analog broadcast.

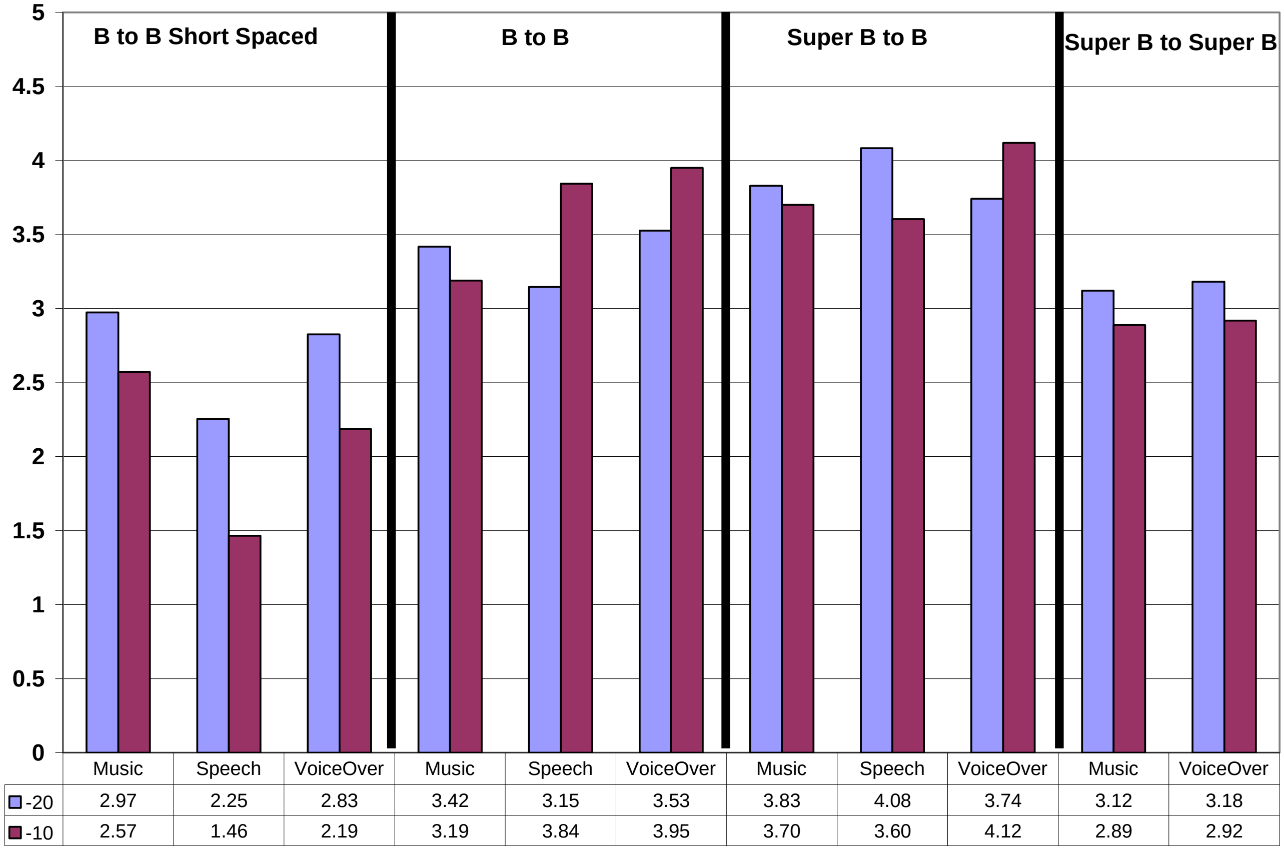
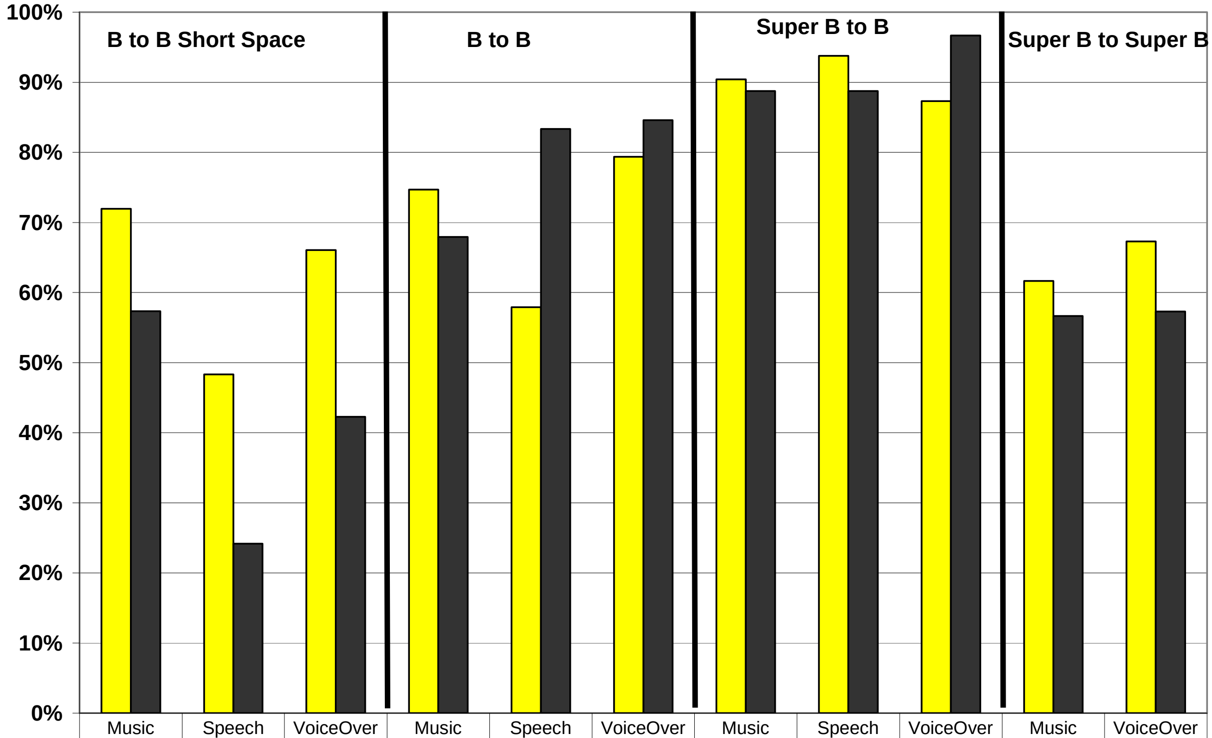


Figure 5: All scenarios at +6 dB D/U

In order to provide some greater clarity about the significance of any drop in MOS score, the test program also asked listeners to comment on whether or not they would continue listening to this broadcast. Figure 6 shows the percentage of people who would continue listening to the program material, given the audio quality. The patterns between MOS and participant listening percentages are highly correlated, as would be predicted. At an MOS level of 3.5 approximately 80% of all listeners say they would continue to listening. At an MOS level of 3.0 the percentage drops to between 60% and 70%. Since listeners rarely use the extremes of the MOS scale (in this case 0 and 5) it is understandable that at an MOS of 4.1, 97% of listeners report that they would continue to listen to the broadcast. Taken together, Figures 5and 6 indicate that the B to B short spaced scenario presents the only situation where the increased digital power has any potential to increase the impact on analog operations.



	Music	Speech	VoiceOver	Music	Speech	VoiceOver	Music	Speech	VoiceOver	Music	VoiceOver
-20	0.72	0.48	0.66	0.75	0.58	0.79	0.90	0.94	0.87	0.62	0.67
-10	0.57	0.24	0.42	0.68	0.83	0.85	0.89	0.89	0.97	0.57	0.57

Figure 6: All scenarios at D/U +6
Percentage of participants continuing to listen

It is important to consider the relevance of the B to B short space results to the overall radio listening experience. The stations selected for these tests represent particularly challenging scenarios that would not be typical of most listening situations. As Table 3 below illustrates, the short spaced scenarios involved particularly severe short spacing that presented particularly challenging environments.

Area	Digital Station	Desired	Desire Freq.	Desired Format	Spacing (kM)	% of Normal Spacing	Terrain
CT/NY	WKCI 101.3 MHz	WPDH	101.5	Rk&Roll	93.18	57	Hilly
		WCBS	101.1	Jack	115.89	71	Shore
		WWBB	101.5	Oldies	145.71	89	Hilly
Detroit	WCSX 94.7 MHz	WMMQ	94.9	Cl Rock	116.69	71	Flat
		WXKR	94.5	Cl Rock	106.56	65	Flat

Table 3 - Spacing of B-to-B Test Stations

In the case of WKCI's impact on WPDH, the stations have only 57% of normal Class B spacing. Only one scenario in Table 3 involves spacing exceeding 71% of normal. Moreover, because none of these test stations other than WXKR uses directional antennas, these results do not take into account in a meaningful way the mitigating impact of directional antennas. If the digital interferer had a directional antenna to minimize the amount of energy broadcast in the direction of the short spacing, the majority of the interference would be expected to be mitigated. As Figure 7 illustrates, approximately 75% of Class B stations with one Class B interferer are fully spaced. Only 10% of Class B stations with one Class B interferer have a short spacing situation with less than 80% of normal spacing as was the case with the majority of the test stations.

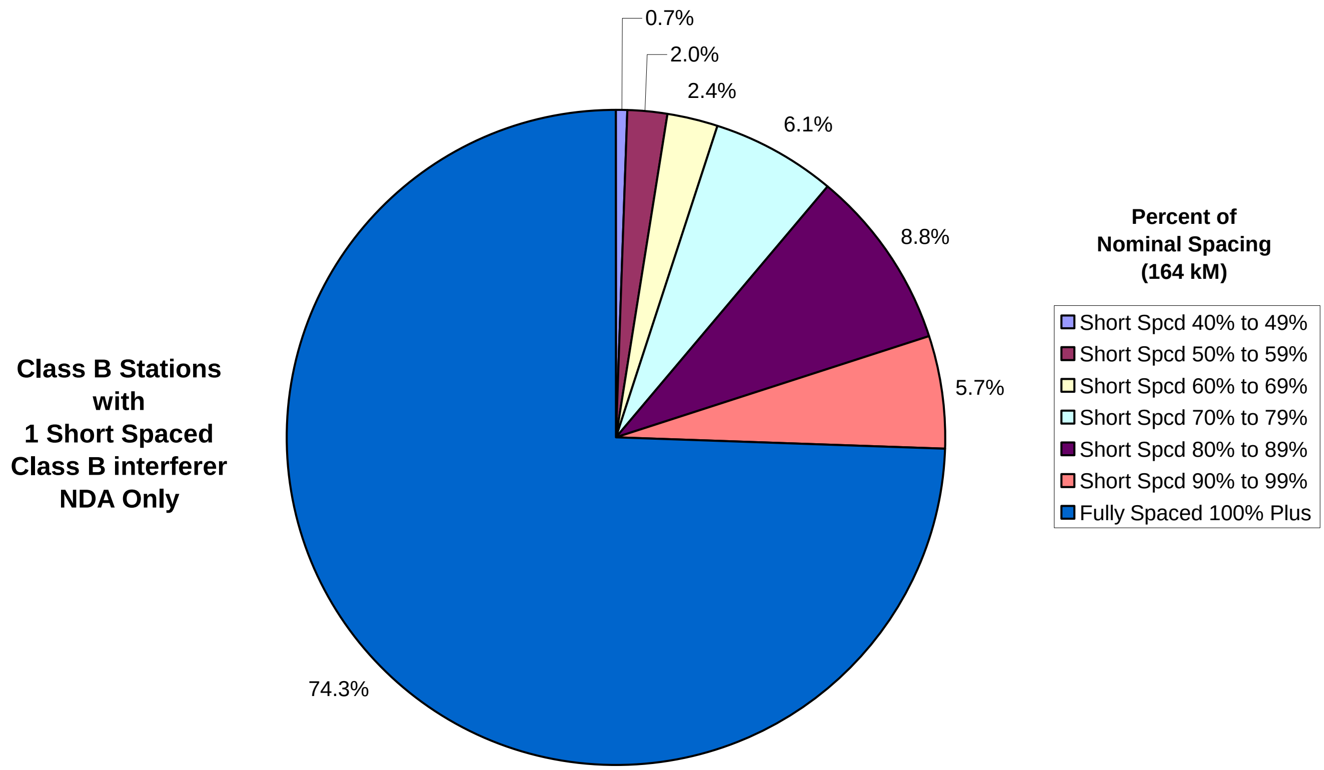


Figure 7 - Class B Stations with 1 Class B Interferer and Nondirectional Antennas

In the case of multiple short spaced Class B interferers, Figure 8 shows nationally there are even fewer instances of severe spacing problems that might increase the risk of digital to analog interference.

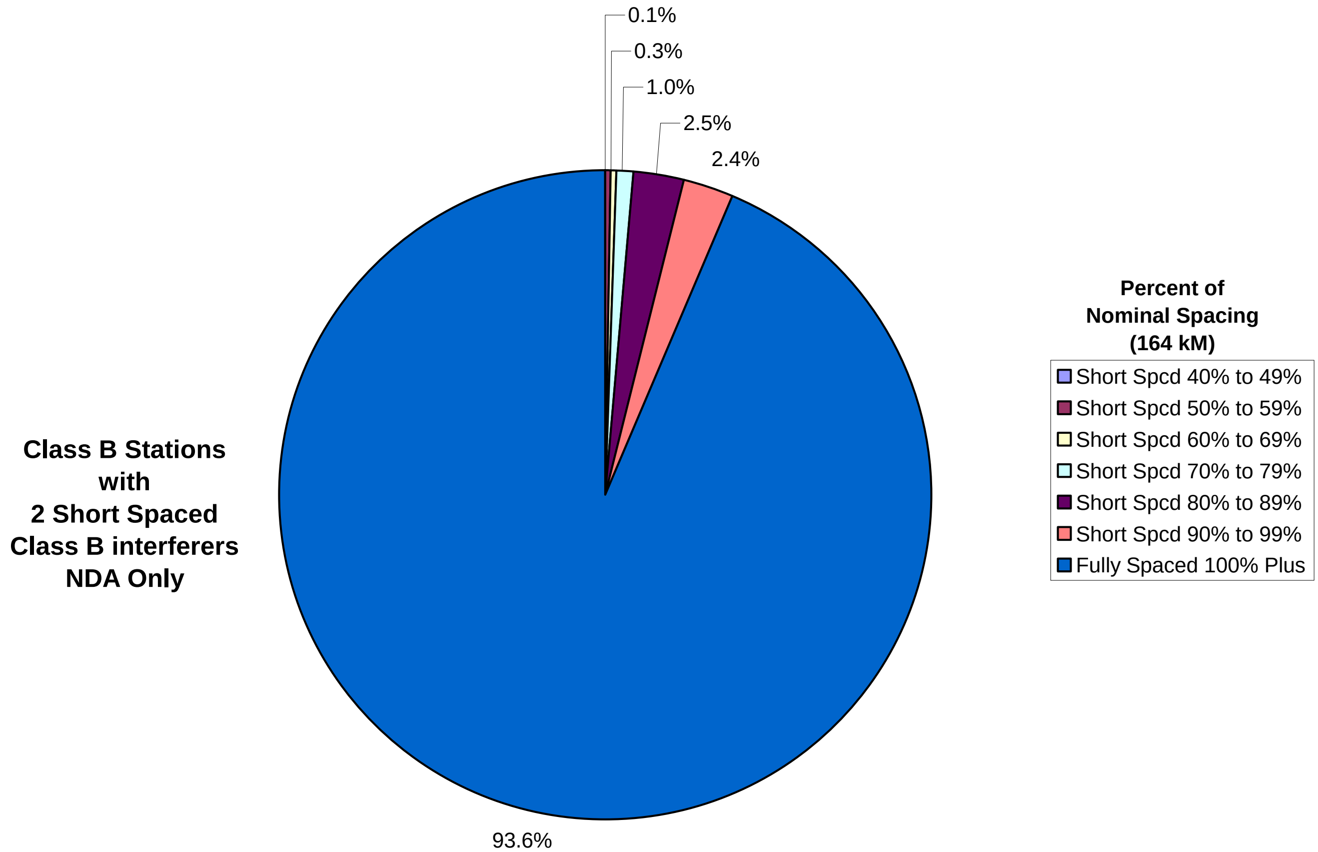


Figure 8 - Class B Stations with 2 Class B Interferers and Nondirectional Antennas

Of the sixty-six stations in this category with nondirectional antennas, fifty-one stations have at least 80% of normal spacing and all but five of those stations have more than 70% of normal spacing. Appendix D contains a detailed report on the spacing of Class B and Super B stations. Thus, it can be assumed that few FM stations in the country with a speech format would have the severe short spacing environment used in these tests. The vast majority of stations have a music format that would mask digital interference and would lack the short spacing associated with interference.

Any analysis of the results also must consider the geographic likelihood of encountering the interference scenario tested. As Figure 9 illustrates, the desired to undesired ratios tested would only occur in a narrow band between the desired and undesired stations.

Black = WMMQ@54 dBu F50/50 Green = WCSX@48dBu F50/10 Red = WMMQ/WCSX DU = 0 to +10 dB

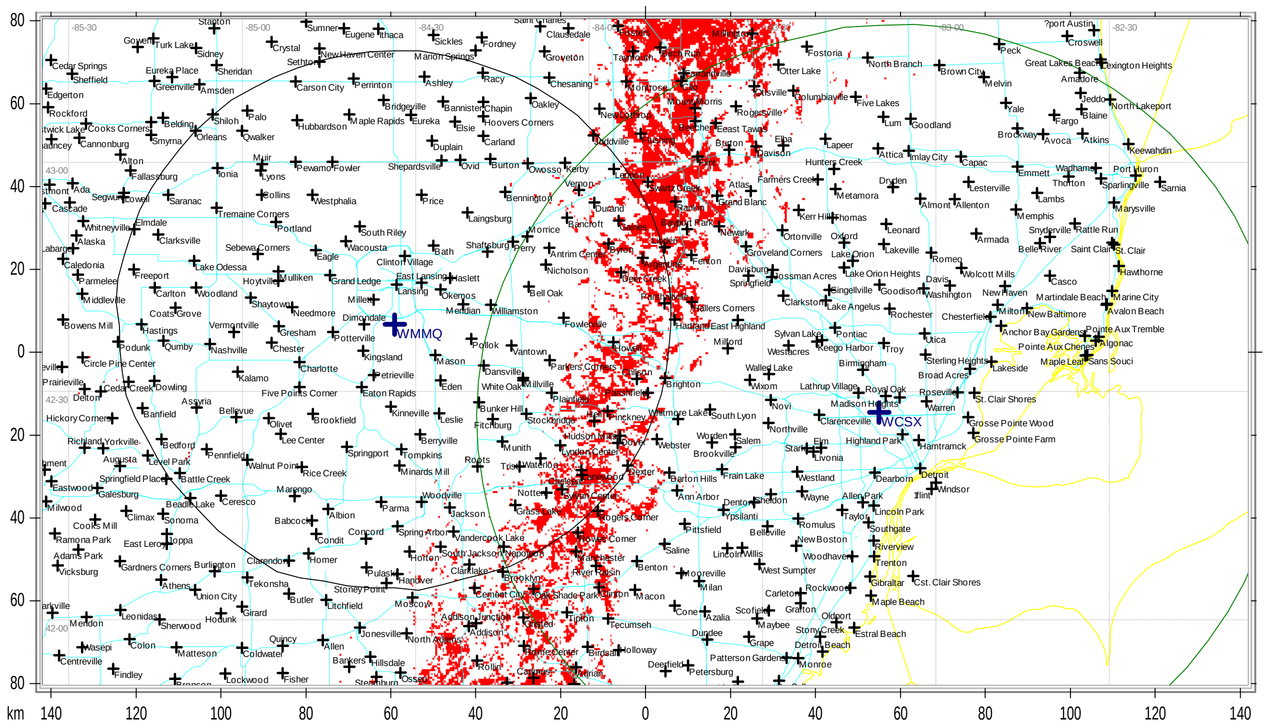


Figure 9 - WCSX to WMMQ

In this case, the area of potential interference for WCSX to WMMQ occurs in a narrow band where the station contours overlap. The vast majority of WMMQ’s listening area would be unaffected by the WCSX signal. Figure 10 illustrates a similar scenario for the impact of WKCI to WCBS

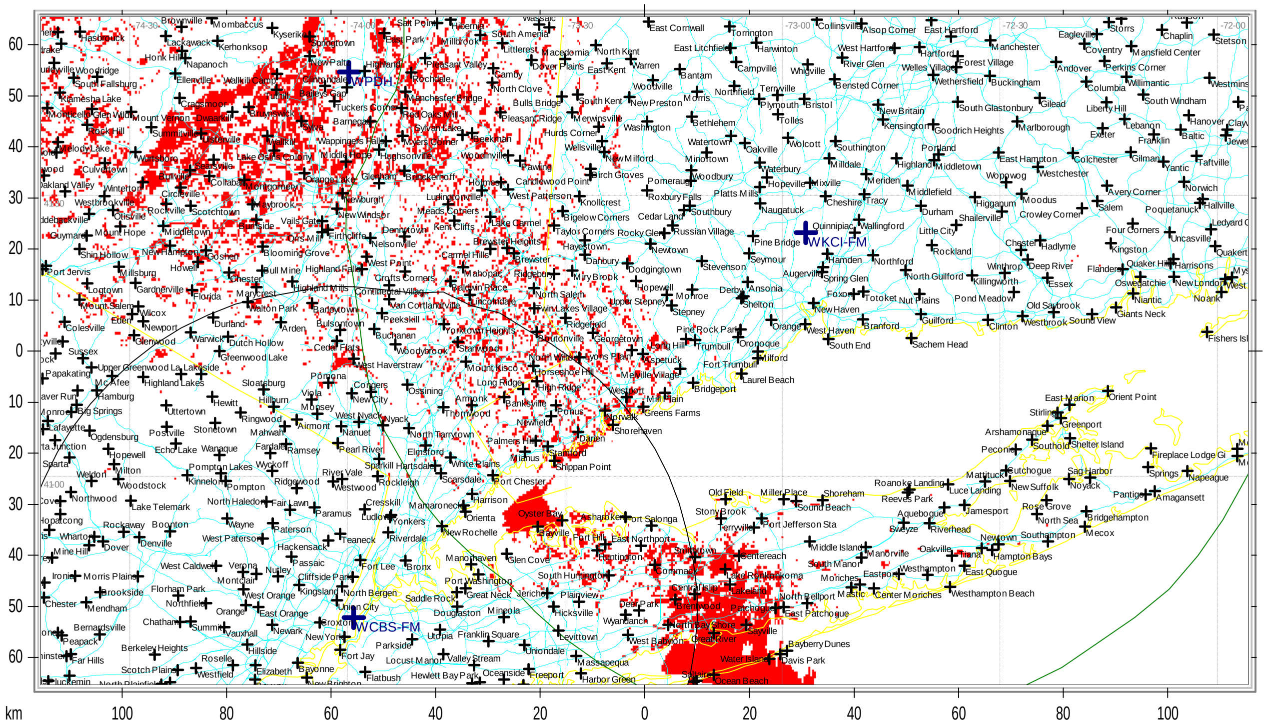


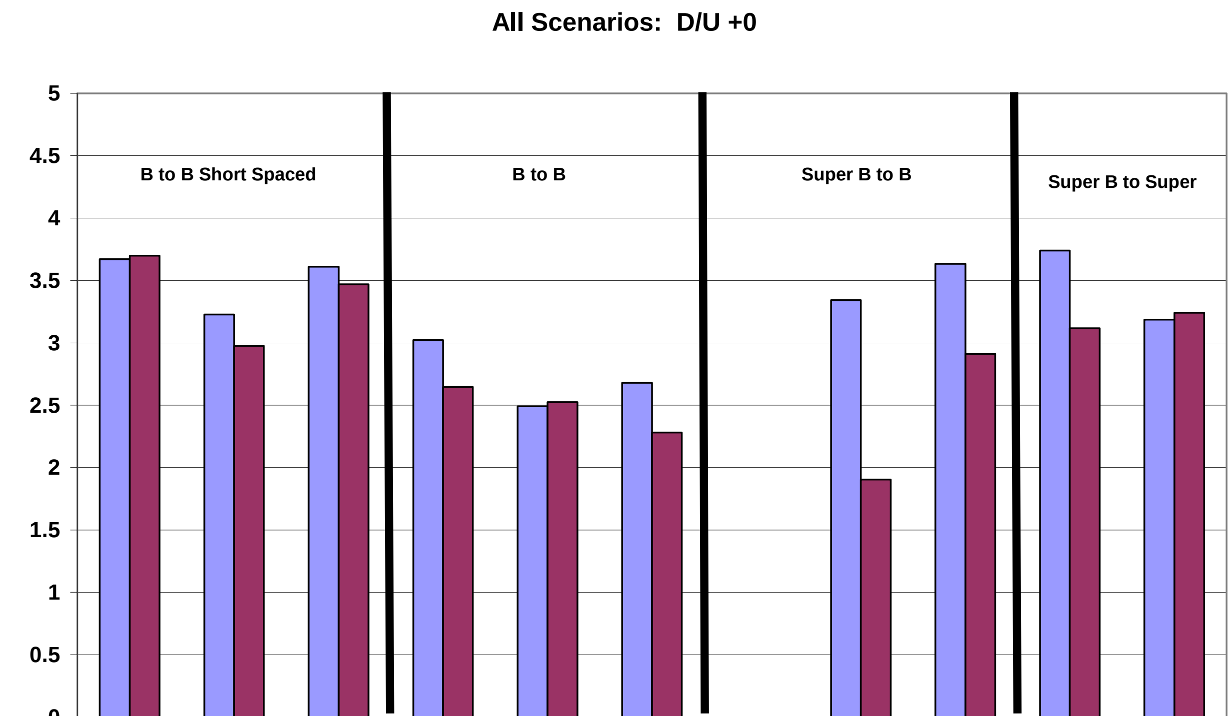
Figure 10 - WKCI to WCBS

Although the short spacing of these stations creates a potential for digital interference within the WCBS protected contour, the area of potentially problematic desired to undesired ratios is quite small compared to the overall WCBS coverage area.

Based on this overall analysis, it can be seen that the increase in digital power can be implemented without a harmful impact in the vast majority of cases.

4.2 Results Outside the Protected Contour

Although areas outside the protected contour do not receive the same protection from harmful interference, it is useful to consider the impact of additional digital power in these areas. Figure 11 shows the overall MOS results at +0 dB D/U, representing listening beyond the analog stations' protected contour. In contrast to results found at +6 dB D/U, at +0 dB D/U participants rated -10 and -20 similarly in B to B short spaced. However, in Super B to B, participants rated speech and voiceover better at -20 than at -10. Due to the nature of the program material collected in the field for the Super B to B condition, there were no music samples to analyze. From these results it can be predicted that the only area with any potential increased impact on analog operations at +0 dB D/U is the Super B to B scenario.



	Music	Speech	VoiceOver	Music	Speech	VoiceOver	Music	Speech	VoiceOver	Music	VoiceOver
-20	3.67	3.23	3.61	3.02	2.49	2.68		3.34	3.63	3.74	3.19
-10	3.70	2.98	3.47	2.65	2.53	2.28		1.90	2.91	3.12	3.24

Figure 11: All Scenarios at +0 dB D/U

Figure 12 shows the percentage of people who would continue listening to the program, given the audio quality. Again, the pattern between MOS and listening is highly correlated. The listening data reinforces the conclusion that the only potential impact on listenership would occur in the Super B to B scenario.

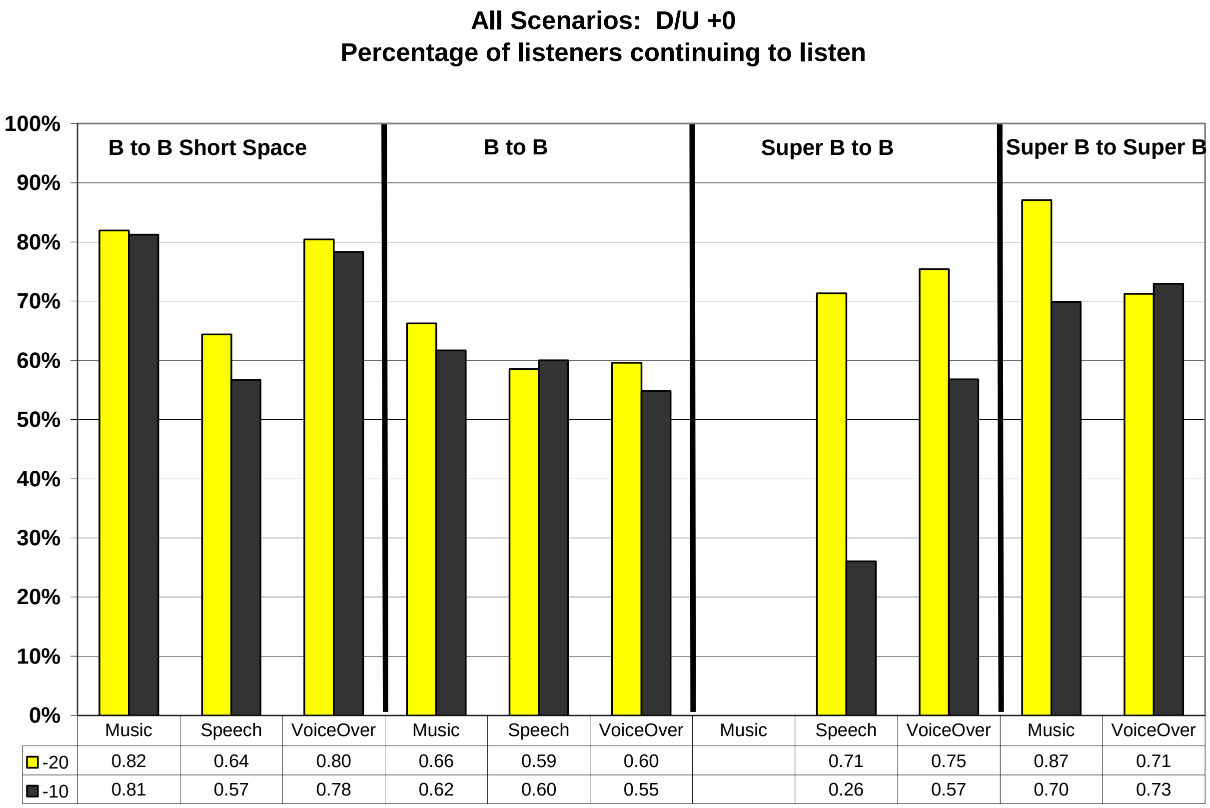


Figure 12_: All scenarios at D/U +0
Percentage of participants continuing to listen

As with the results for the short spaced B to B interference inside the protected contour, it is important to consider the significance of the results on typical listening situations. There are only 114 Super B stations operating in the United States, representing a small fraction of the total number of FM stations. More than half the Super B stations are located in California, further minimizing the scope of any potential interference from Super B stations. In the tests conducted in the Los Angeles area, KOST operated as the digital interferer to the desired analog signal from KSCF. Figure 13 illustrates the location of these stations. Although KOST operates at a power level that reaches well beyond its 54 dBu contour, the test location with the appropriate desired to undesired ratio was outside the KSCF protected contour.

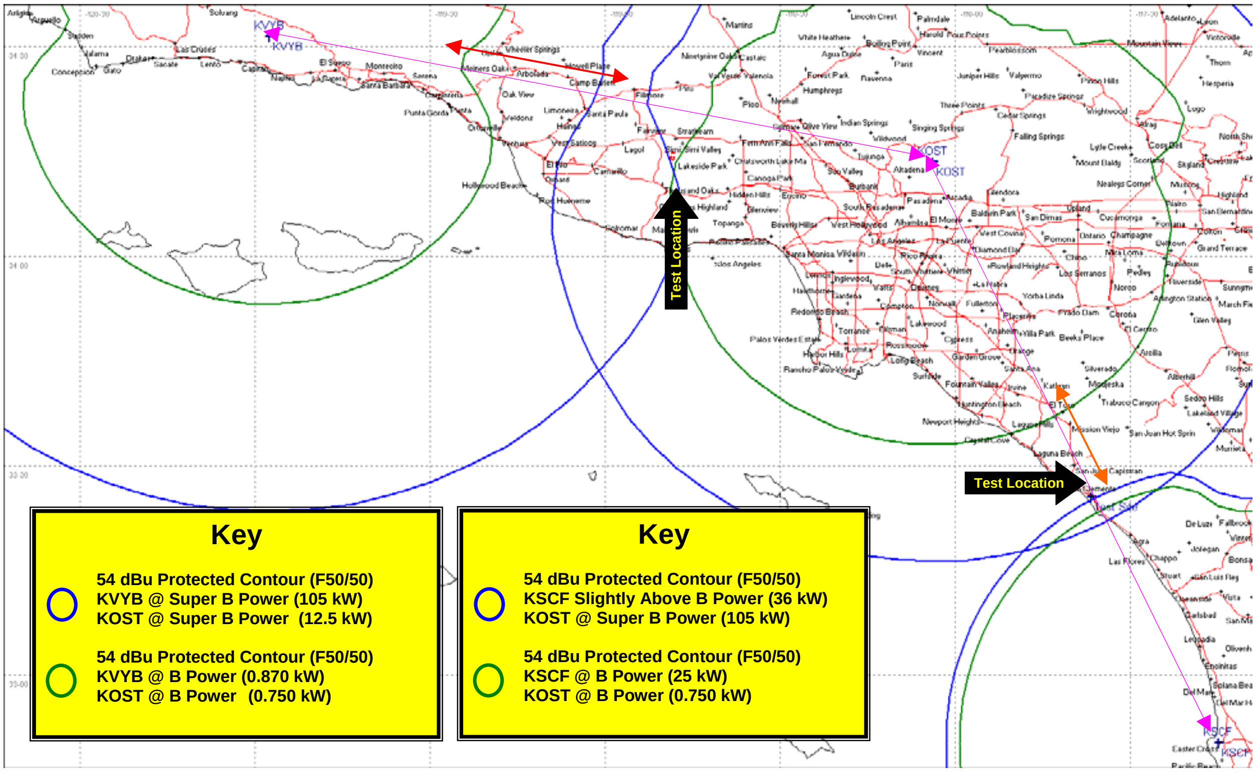


Figure 13 - KOST and KSCF Service Areas and Test Location

It is also important to note that KOST operates at a particularly high power level. It operates at more than 12 dB over the normal Class B power level. This is typical of California Super B stations, which operate on average at a much higher analog power than the Super B stations in other parts of the country. Figure 14 illustrates the disproportionately high power of California Super B stations such as KOST. The impact in other regions would be expected to be greatly reduced due to the more moderate analog power levels of those stations.

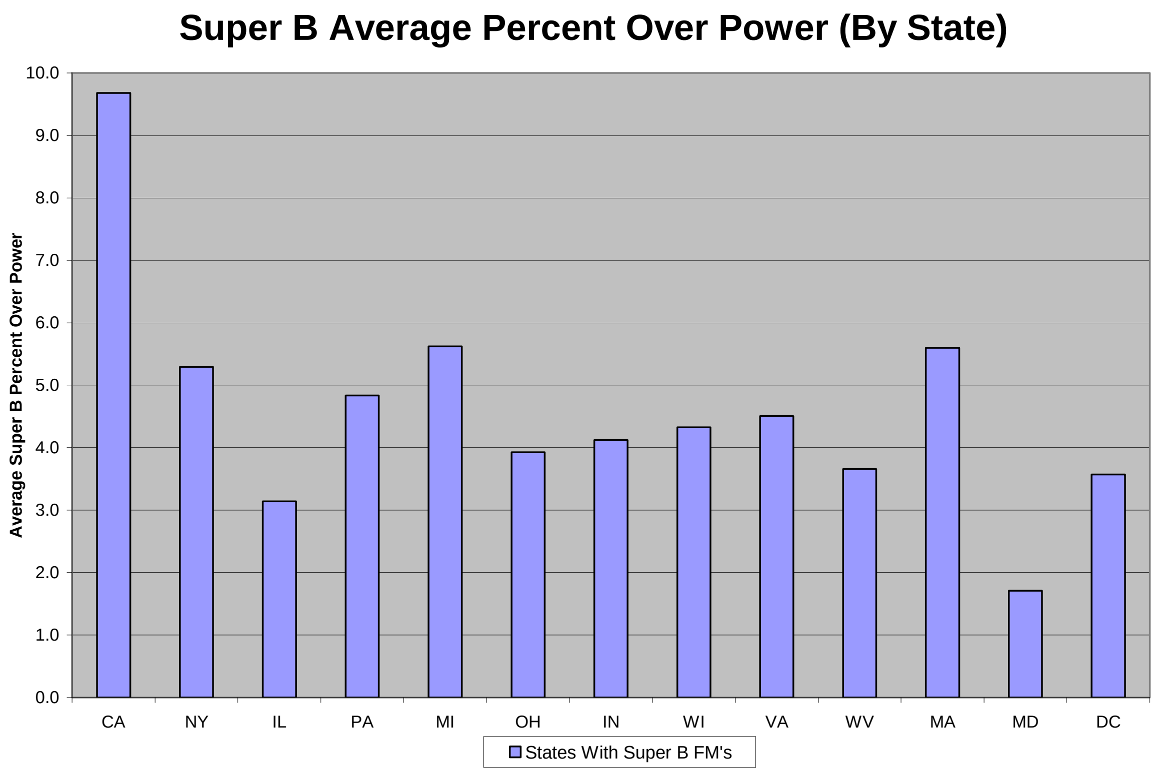


Figure 14 – Average Super B Power By State

Based on the small number of Super B stations and the limited geographic scope of those stations, the impact of Super B stations on Class B stations should not preclude the implementation of higher power digital broadcasts. Any potential increase in digital interference from a Super B station can be addressed on a case-by-case basis.

5. Conclusions

These results present a comprehensive view of the benefits and potential implications of an increase in digital power in the FM HD Radio system. The tests confirmed the proposed increase in digital power results in a significant increase in digital coverage, thereby enabling broadcasters to more accurately replicate their analog coverage area with reliable digital service. At the same time, the subjective evaluation tests demonstrate the higher power can be implemented without increasing the risk of impact to analog broadcasts in the vast majority of cases. Any actual interference that may occur as a result of an increase in power can be addressed by the stations or the FCC on a case-by-case basis.

List of Appendices

Appendix A -	**HD Radio Compatibility with Existing FM Analog Transmission at Elevated Carrier Levels Test Procedure**
Appendix B -	**FM HD Radio System Performance at Elevated Carrier Levels**
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Appendix D -	**Class B and Class Super B Spacing Statistics**